# A BRIEF DISCUSSION OF A RECENT EXPLOSIVE ACCIDENT AT THE NAVAL SURFACE WARFARE CENTER

By

M. M. Swisdak, Jr.
Naval Surface Warfare Center/Indian Head Division

and

E. J. Deschambault
Naval Surface Warfare Center/Indian Head Division

**ABSTRACT**

On 10 February 1998, there was an explosive mishap at the Indian Head Division of the Naval Surface Warfare Center. There were no fatalities or injuries, but significant property damage did occur. The incident occurred in a 150-gallon horizontal mixer during the processing of a new propellant. This paper will describe the event and the damage that was produced. It will also describe possible causes for the event and some of the testing that has been conducted as part of the investigation.

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## INTRODUCTION

In 1996, the Indian Head Division of the Naval Surface Warfare Center began working in partnership with OEA, a private company based in Colorado to conduct research on AIRBAG Propellant. The work is being performed under a CRADA (Cooperative Research and Development Agreement). Indian Head Division is partnering with OEA in conducting research leading to the development of the new airbag propellant because of its expertise in the areas of propellant formulation and development. This partnership furthers Indian Head's expertise and keeps its propellant formulation, development, and manufacturing capabilities viable and ready for national defense.

The developmental task involved considerable effort, which addressed various issues related to formulation, processing, productivity, quality and safety. By January 1998, the effort had transitioned from the development phase to the production phase where four production-scale batches (150 gallon mixes) were being produced for qualification test and evaluation.

On 10 February 1998 at about 0100, during the processing of the fourth and final qualification batch, an explosive mishap occurred in Building 1026; this incident occurred during the addition of dry RDX to the mixer, prior to the start of the mixing process. This mishap destroyed the mixer and its building and damaged many of the surrounding structures. There were no fatalities and no injuries. The damage to the building and the surrounding complex has been estimated at several million dollars.

The operation was being controlled remotely from a hardened control room that was located about 90 feet from the Mixer Building. There were four people in the Control Room at the time of the mishap.

The JAGMAN Investigation has been completed. The technical investigation into the causes of the event is still ongoing. This paper, therefore, represents a progress report, rather than a definitive, final report. Moreover, the exact formulation of the airbag propellant and the details of its processing are proprietary. Therefore, these will be presented only in generic terms.

## PROCESS DESCRIPTION

At the time of the event, the following process was being used to manufacture the propellant. Prior to the actual mixing, a rubber compound is dissolved in an organic solvent (tetrahydrofuran (THF)). The mixer is opened and the rubber/THF mixture is placed inside with small amounts of two other dry ingredients, an anti-oxidant and a cure catalyst. When this step is completed, the mixer lid is closed and all personnel leave the building for the hardened control room. When everyone is in the control room, dry, finely ground RDX (average particle size > 5 microns) is added remotely to the mixer bowl.

After completion of the RDX addition, personnel re-enter the mixer building and the mixer bowl is inspected. If everything is normal, they again leave the building and return to the Control Room. At this point, the mixer is started, blending the ingredients together.

This process is similar (same RDX addition system, same mixing equipment, similar RDX particle size, similar solvents) to propellant manufacturing procedures that have been safely used at the Indian Head Division for many years.

## FACILITY DESCRIPTION

Building 1026 is a multi-story, reinforced concrete, earth-bermed structure with multiple tunnel entrances and a frangible, built-up roof. The ground floor area is approximately 30’ x 36’. The wall height is approximately 40 feet. The earth-berm extends from a point about 5-feet from the top of the wall at a slope of 1-1/2 to 1, natural grade. A heavy concrete floor is located about 13 feet above the ground floor of the structure. A lighter, frangible mezzanine is located about 23 feet above the ground floor. Figure 1 is a photograph of the exterior of a similar structure. Figure 2 is a sketch of the interior layout of the building.

**FIGURE 1. EXTERIOR OF SIMILAR STRUCTURE**

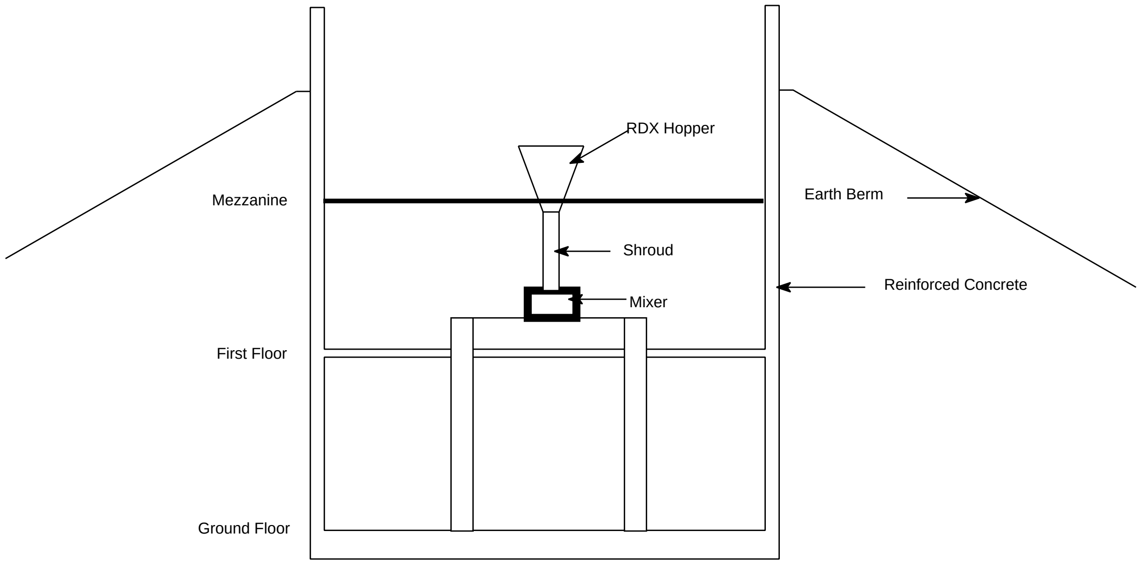


**FIGURE 2. BUILDING 1026 ARRANGEMENT**

The RDX is brought into the building in a wheeled hopper cart. The hopper is positioned on the Mezzanine Level directly above the mixer bowl. A cloth shroud with a conductive liner is attached to the bottom of the hopper and is used to direct the RDX into the bowl. Air-operated vibrators are attached to the exterior of the hopper to facilitate the flow of RDX. The flow of RDX from the hopper is controlled by an air-actuated valve that raises or lowers a seal located at the bottom of the hopper.

## THE EVENT

At the start of the process, there was about 550 pounds of RDX located in the hopper. When the mishap occurred, about 100 pounds of this RDX had flowed from the hopper into the mixer. This addition process, while not completely smooth, was not atypical. Initially, a clump weighing about 25 pounds fell from the hopper into the mixer. A short time later, an additional 70-75 pounds of material fell into the mixer. Shortly after this, the event occurred.

None of the operators who were located in the Control Room noticed anything out of the ordinary before the event. At the time of the mishap, there were two video cameras operating in the bay that recorded the event. A detailed, frame-by-frame analysis of these video tapes indicated that the first event was a burning-type reaction, starting either in the mixer bowl or shroud during RDX addition. About 60-80 milliseconds after the first evidence of burning, there is a white flash and all subsequent data was lost.

Most of the variables pertinent to the loading process are also recorded onto a computer file. The event time indicated by these computerized records is in apparent agreement with the times estimated from the video tapes.

## OBSERVED DAMAGE

The event caused the top of the walls of the structure to deflect outward about 3.7 feet. This deflection began at a hinge point located 13.3 feet below the top of the wall. The mezzanine and first floors were blown down to the ground floor of the structure. Figures 3 and 4 show two views of this damage.

**FIGURE 3. AERIAL VIEW OF BUILDING**

**FIGURE 4. BUILDING 1026 DAMAGE**

Most of the debris was projected vertically upward, thus limiting the extent of the horizontal dispersion. The majority of this debris was collected within 400 feet of the building. The most distant debris piece that was found was about 700 feet from the structure.

The damage that was observed in the surrounding structures appeared to be directional rather than being symmetrical centered on the structure. This is attributed to the numerous tunnel entrances to the building. Under normal circumstances, the airblast from this type of event would be symmetrical. This phenomenon has been studied by NCEL (Naval Civil Engineering Laboratory, now Naval Facilities Engineering Service Center (NFESC)) and is described as airblast from a four wall, vented cubicle[1]. In our situation, however, another event is superimposed on this airblast. That is the highly directional airblast that is directed out each of the tunnels. It is this non-classical, directed-flow airblast that causes the majority of the observed damage to the surrounding structures[2]. The following figures (Figure 5 through Figure 9) show some of this damage.

**FIGURE 5. DAMAGE TO NEARBY CONCRETE BLOCK STRUCTURE**

**FIGURE 6. VIEW FROM TUNNEL ENTRANCE**

**FIGURE 7. TYPICAL DAMAGE**

**FIGURE 8. EXTERNAL DAMAGE**

Windows were broken both on base and in the town of Indian Head (maximum range of about 6000 feet). Because of atmospheric conditions, which caused the sound to focus, the event was heard over 25 miles away.

## MAXIMUM CREDIBLE EVENT (MCE) ANALYSIS

This observed damage was used by the Naval Facilities Engineering Services Center to estimate the size of the event. Based on their analysis[3], the event had a yield between 400 and 565 pounds of TNT. They further indicate that because of the design conservatism used in their computations, the actual MCE should be closer to the high estimate of 565 pounds. For the loading densities (explosive weight divided by internal volume of structure) present at the time of the event, the TNT equivalence of TNT and RDX is about 1[4]. Therefore, the MCE was about 570 pounds of RDX.

**FIGURE 9. DAMAGE TO NEARBY EQUIPMENT BUILDING**

## CAUSAL ANALYSIS

As indicated above, the initial event was a fire or burning that then transitioned to a detonation. Thus, the causal analysis has focussed on the potential events that could have triggered that initial burning. The following broad categories have been considered: Heat, Mechanical, Chemical, Electrical, Sabotage, and Procedures. Each of these broad categories was then further broken down. As an example, under the Heat Category, the following sub-categories were considered: Fire external to the building, Fire internal to the building, Other heat sources external to the building, Other heat sources internal to the building, and Heat sources internal to the mixer. Each of these sub-categories was then accepted or rejected as determined by the physical evidence. Where the evidence was incomplete or data were lacking, experimental efforts were proposed to obtain the results.

Obvious sources such as lightning and fire are easily eliminated. More difficult to eliminate are chemical incompatibilities that might lead to an exothermic reaction. All of the individual ingredients have been tested and were within specification. Differential Scanning Calorimetry (DSC) tests on combinations of ingredients have been performed with no major anomalies uncovered.

Impact, friction, and ESD testing has been performed on the RDX used in this process with no anomalies being discovered. When the tests were repeated in the presence of THF vapor at an elevated temperature, there is an indication that the material becomes more sensitive. Testing is continuing in this area.

The charging characteristics of falling RDX have also been examined. Small-scale tests (less than 10 grams) have been conducted using both aluminum oxide as a simulant and RDX from the same grinding lot. Larger scale tests are being planned and full-scale tests have not been ruled out.

A computer model of the electrical properties of the system has been completed. This model requires as input the charging characteristics of the RDX being determined from the tests described in the previous paragraph. Preliminary results using the characteristics determined from the small scale experiments indicate that sufficient charge can be generated by the falling RDX to cause a Brush Discharge which would have sufficient energy to ignite the vapor/air mixture if it were within its flammability limits.

The question that was addressed was whether the organic solvent vapors were within their flammability limits. This could only be addressed by a series of experiments in which the vapor concentration was measured at several locations within the bowl and shroud as a function of time. Vapor pressures were measured by two methods—(1) individual samples were collected and later analyzed and (2) Fourier Transform Infra Red (FTIR) Spectroscopy was used to obtain vapor concentrations.

Based on discussions with the operators involved in the incident, a timeline of events was established. This timeline was followed in the vapor pressure experiments and assured that the data collected was representative of the event. Both the grab samples and the FTIR analysis indicated that the THF vapor was well within its flammability limits for most of the mixing process.

An added complication to this is the presence of RDX dust in the organic vapor. It has been hypothesized that an RDX dust/THF vapor hybrid might actually be more sensitive to ESD than either of the components separately. This will be investigated by further testing.

Testing is continuing. Until all of the testing is completed and the official Technical Investigation Report issued, no cause can be assigned with certainty. Based on the testing that has been conducted thus far, a possible cause of the event was a fire started by an electrostatic discharge (ESD) that transitioned to a detonation. Nearly all other ignition sources have been considered and most have been eliminated.

# REFERENCES


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